AD NO. ____________________________
DTC PROJECT NO. 8-CO-160-UXO-020
REPORT NO. ATC-10004

UXO TECHNOLOGY DEMONSTRATION SITE

ACTIVE SITE SCORING RECORD NO. 934

SITE LOCATION:
U.S. ARMY ABERDEEN PROVING GROUND

DEMONSTRATOR:
NAEVA GEOPHYSICS, INC
P.O. BOX 7325
CHARLOTTESVILLE, VA 22906

TECHNOLOGY TYPE/PLATFORM:
EM61 MKII/TOWED

PREPARED BY:
U.S. ARMY ABERDEEN TEST CENTER
ABERDEEN PROVING GROUND, MD 21005-5059

JULY 2009

Prepared for:
U.S. ARMY ENVIRONMENTAL COMMAND
ABERDEEN PROVING GROUND, MD 21010-5401

U.S. ARMY DEVELOPMENTAL TEST COMMAND
ABERDEEN PROVING GROUND, MD 21005-5055

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J. Stephen McClung		July 2009
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14. ABSTRACT

This scoring record documents the efforts of NAEVA Geophysics, Inc. to detect and discriminate inert unexploded ordnance (UXO) utilizing the APG Standardized UXO Technology Demonstration Site Blind Grid, Open Field, and Active Sites. This Scoring Record was coordinated by J. Stephen McClung and the Standardized UXO Technology Demonstration Site Scoring Committee.
Organizations on the committee include the U.S. Army Corps of Engineers, the Environmental Security Technology Certification Program, the Strategic Environmental Research and Development Program, the Institute for Defense Analysis, the U.S. Army Environmental Command, and the U.S. Army Aberdeen Test Center.

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NAVEA Geophysics, Inc., APG, Standardized UXO Technology Demonstration Site, blind grid, open field, active, EM61 MKII/ Towed array.

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TABLE OF CONTENTS

PAGE

1.1 ACKNOWLEDGMENTS i

SECTION 1. GENERAL INFORMATION

1.1 BACKGROUND 1
1.2 SCORING OBJECTIVES 1
1.2.1 Scoring Methodology 2
1.2.2 Scoring Factors 4

SECTION 2. DEMONSTRATION

2.1 DEMONSTRATOR INFORMATION 7
2.1.1 Demonstrator Point of Contact (POC) and Address 7
2.1.2 System Description 7
2.1.3 Data Processing Description 9
2.1.4 Data Submission Format 11
2.1.5 Demonstrator Quality Assurance (QA) and Quality Control (QC) 11
2.1.6 Additional Records 12
2.2 APG SITE INFORMATION 13
2.2.1 Location 13
2.2.2 Soil Type 13

SECTION 3. FIELD DATA

3.1 DATE OF FIELD ACTIVITIES 15
3.2 AREAS TESTED/NUMBER OF HOURS 15
3.3 TEST CONDITIONS 15
3.3.1 Weather Conditions 15
3.3.2 Field Conditions 15
3.3.3 Soil Moisture 15
3.4 FIELD ACTIVITIES 16
3.4.1 Setup/Mobilization 16
3.4.2 Calibration 16
3.4.3 Downtime Occasions 16
3.4.4 Data Collection 16
3.4.5 Demobilization 16
3.5 PROCESSING TIME 17
3.6 DEMONSTRATOR’S FIELD PERSONNEL 17
3.7 DEMONSTRATOR’S FIELD SURVEYING METHOD 17
3.8 SUMMARY OF DAILY LOGS 17

SECTION 4. TECHNICAL PERFORMANCE RESULTS

PAGE

4.1 ROC CURVES USING ALL ORDNANCE CATEGORIES 19
4.2 PERFORMANCE SUMMARIES 20
4.3 EFFICIENCY, REJECTION RATES, AND TYPE CLASSIFICATION 23
4.4 LOCATION ACCURACY 23
4.5 STATISTICAL COMPARISONS 23

SECTION 5. ON-SITE LABOR COSTS

SECTION 6. APPENDIXES

A TERMS AND DEFINITIONS . . . . A - 1
B DAILY WEATHER LOGS . . . . B - 1
C SOIL MOISTURE . . . . C - 1
D DAILY ACTIVITY LOGS . . . . D - 1
E REFERENCES . . . . E - 1
F ABBREVIATIONS . . . . F - 1
G DISTRIBUTION LIST . . . . G - 1

SECTION 1. GENERAL INFORMATION

1.1 BACKGROUND

Technologies under development for the detection and discrimination of munitions and explosives of concern (MEC) - i.e., unexploded ordnance (UXO) and discarded military munitions (DMM) require testing and evaluation in order for their performance to be characterized. It is imperative that this characterization be performed on a realistic test site in order to successfully gauge how well a system may perform at an actual munitions response site. To that end, the Active Response Demonstration Site has been developed at Aberdeen Proving Ground (APG), Maryland. This site provides the ability to test technologies under development on an actual test range that has a large number of UXO, MEC, and DMM that have not been cleared. Realistic characteristics of the Active Response Site include significant quantities of live UXO, range scrap, and excess debris. Testing at this site is independently administered and analyzed by the government for the purposes of characterizing technologies, tracking performance with system development, comparing performance of different systems, and validating the standardized UXO test sites.

The Active Response Demonstration Site Program is a multiagency program spearheaded by the U.S. Army Environmental Command (USAEC). The U.S. Army Aberdeen Test Center (ATC) and the U.S. Army Corps of Engineers Engineering Research and Development Center (ERDC) provide programmatic support. The program is being funded and supported by the Environmental Security Technology Certification Program (ESTCP), the Strategic Environmental Research and Development Program (SERDP), and the U.S. Army Environmental Quality Technology (EQT) Program.

1.2 SCORING OBJECTIVES

The objective in the Active Response Demonstration Site Program is to evaluate the detection and discrimination capabilities of a given technology under realistic conditions. The only UXO that were cleared before vendors were allowed to survey the area are items that pose a safety hazard.

The evaluation objectives are as follows:

a. To determine detection and discrimination effectiveness under a realistic scenario.

b. To determine cost, time, and manpower requirements to operate the technology.

c. To determine the demonstrator’s ability to analyze survey data in a timely manner and provide prioritized target lists with associated confidence levels.

d. To provide independent site management to enable the collection of high quality ground-truth (GT) and geo-referenced data for post-demonstration analysis.

1.2.1 Scoring Methodology

The Active Response Demonstration Site is divided into 20 meter by 20 meter grids. The grids are ranked based upon the density of items that have accumulated in each respective grid cell. After multiple vendors surveyed the area with their UXO detection/discrimination systems, half of the 2 acre site was cleared of all metallic items. This clearing of the metallic anomalies from the 2 acre Active Response Demonstration Site was broken into three phases. In the first phase, the target lists from all of the vendors that have surveyed the site were combined in order to create a master target list that was used in the initial phase of the site clearance. Once Phase 1 was completed, a secondary sweep of the site took place and another recovery operation was performed. After the secondary investigation was completed, the Naval Research Laboratory (NRL) conducted a survey of the site with their Multiple Towed Array Detection System (MTADS). This system is known for its effectiveness and ability to detect metallic items. Once the NRL MTADS surveyed the site, ATC collected their data and conducted another intrusive operation in order to remove any additional anomalies. During each clearance operation, the exact placement of all the metallic items was carefully measured in order to create a GT for each grid cell. Once the GT for each cell was compiled, each item in the GT was classified as being either ordnance or clutter. Clutter items are defined as metallic items that do not have enough explosives to be considered safety hazards. Fuzes that no longer have their boosters, fins, fragmented items, and items that were never part of any ordnance item, for example, were classified as clutter. The remaining objects that pose a safety risk were classified as ordnance. This GT will be used to score all of the vendors that had previously surveyed the site, prior to clearance.

a. The scoring of the demonstrator's performance is conducted in two stages. These two stages are termed the response stage and discrimination stage. For both stages, the probability of detection (P_d) and the false alarms are reported as receiver-operating characteristic (ROC) curves. False alarms are divided into those anomalies that correspond to clutter items, measuring the probability of false positive (P_{fp}), and those that do not correspond to any known item, termed background alarms.

b. The response stage scoring evaluates the ability of the system to detect targets without regard to ability to discriminate ordnance from other anomalies. This list is generated with minimal processing.

c. The discrimination stage evaluates the demonstrator's ability to correctly identify ordnance as such and to reject clutter. For the discrimination stage, the demonstrator provides the scoring committee with the output of the algorithms applied in the discrimination-stage processing. The values in this list are prioritized based on the demonstrator's determination that an item is ordnance. Thus, higher output values are indicative of higher confidence that an ordnance item is present at the specified location. For digital signal processing, priority ranking is based on algorithm output. For other discrimination approaches, priority ranking is based on human (subjective) judgment. The demonstrator also specifies the threshold in the prioritized ranking that provides optimum performance, (i.e., that is expected to retain all detected ordnance and rejects the maximum amount of clutter).

d. The demonstrator is also scored on efficiency and rejection ratio, which measures the effectiveness of the discrimination stage processing. The goal of discrimination is to retain the greatest number of ordnance detections from the anomaly list, while rejecting the maximum number of anomalies arising from nonordnance items. Efficiency measures the fraction of detected ordnance retained after discrimination (give ratio), while the rejection ratio measures the fraction of false alarms rejected. Both measures are defined relative to performance at the demonstrator-supplied level below which all responses are considered noise (i.e., the maximum ordnance detectable by the sensor and its accompanying false positive rate or background alarm rate).

e. Depending on the density of items that are in a given grid, there exists the possibility of having anomalies within overlapping halos (halo = 1-m diameter) and/or multiple anomalies within halos. In these cases, the following scoring logic is implemented:

(1) For each anomaly supplied by the vendor, the vendor can be only given credit for finding, at most, one ordnance item. In other words, if a vendor gives only one anomaly that is within 0.5 meters from six grenades, he will only be given credit for finding one of those six grenades.

(2) In situations where multiple anomalies exist within a single R_{halo}, the anomaly with the strongest response or highest ranking will be assigned to that particular GT item. For example, if a vendor supplies two anomalies that are within 0.5 meters from a given ordnance item, and one of the anomalies has a signal level (response level if we are calculating the response stage value, or the discrimination ranking if we are calculating the discrimination stage value) of 0 while another anomaly has a signal level 1, then the anomaly with a signal level of 1 will be given credit for finding that particular GT item. The anomaly with a signal level of 0 will then be free to be possibly attached to another GT item if there is another GT item that is within 0.5 meters from that anomaly.

(3) For overlapping R_{halo} situations, ordnance has precedence over clutter. The anomaly with the strongest response or highest ranking that is closest to the center of a particular GT item gets assigned to that item. Remaining anomalies are retained until all matching is complete. In other words, if a vendor supplies only one anomaly that is within 0.5 meters of both an ordnance and clutter item, the vendor will be given credit for finding the ordnance item. On the other hand, if a vendor supplies only one anomaly that is within 0.5 meters of two ordnance items, then the vendor will be given credit for finding whichever ordnance item is closest to the vendor's anomaly.

(4) Anomalies located within any R_{halo} that do not get associated with a particular GT item are thrown out and are not considered in the analysis. As an example, if a vendor supplies two anomalies that are within 0.5 meters from a GT item, and this is not an overlapping halo situation, then one of the anomalies will be used so that the vendor gets credit for finding this GT item, but the second anomaly will neither be used to give the vendor credit for finding a GT item nor will this item be counted as a background alarm.

(5) All anomalies that are supplied by the vendor that are either outside of the boundary of the active site or are within 1 meter of the boundary of the active site will be thrown out and will not be counted as background alarms nor will they contribute to the vendors P_d or P_{fp}. Likewise, all GT items that are outside of the boundary of the active area or are within 1 meter of the boundary of the active site will be thrown out and will not contribute to the vendor's P_d or P_{fp}. If a vendor supplies an anomaly that is within the active site and more than 1 meter away from the boundary of the active site, and this anomaly is within the halo of a GT item that is closer than 1 meter to the boundary of the active site, but this anomaly is not within the halo of a GT item that is further than 1 meter away from the boundary of the active site, then this anomaly will neither be counted as a background alarm, nor will it contribute to the vendors P_d or P_{fp}.

f. All scoring factors are generated utilizing the Standardized UXO Probability and Plot Program, version 4.0 using the earlier version 3.11 rules so results can be compared to surveys done in the blind grid and open field area of the Standardized UXO Test Site.

1.2.2 Scoring Factors

Factors to be measured and evaluated as part of this demonstration include:

a. Response Stage ROC curves:

(1) Probability of Detection (P_d^{res}).

(2) Probability of False Positive (P_{fp}^{res}).

(3) Background Alarm Rate (BAR^{res}).

b. Discrimination Stage ROC curves:

(1) Probability of Detection (P_d^{disc}).

(2) Probability of False Positive (P_{fp}^{disc}).

(3) Background Alarm Rate (BAR^{disc}).

c. Metrics:

(1) Efficiency (E).

(2) False Positive Rejection Rate (R_{fp}).

(3) Background Alarm Rejection Rate (R_{BA}).

d. Other:

(1) Location accuracy.

(2) Equipment setup, calibration time, and corresponding worker-hour requirements.

(3) Survey time and corresponding worker-hour requirements.

(4) Reacquisition/resurvey time and worker-hour requirements (if any).

(5) Downtime due to system malfunctions and maintenance requirements.

SECTION 2. DEMONSTRATION

2.1 DEMONSTRATOR INFORMATION

2.1.1 Demonstrator Point of Contact (POC) and Address

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2.1.2 System Description (provided by demonstrator)

a. Dual EM61 MKII Towed Array:

(1) This system will be employed to survey the calibration lanes, blind grid, open field, and the active response site. During the fall of 2003, NAEVA developed and field tested a new towed array system for the Geonics EM61 MKII. Two 1- by 0.5-meter coils were encased in a durable poly-plastic sled that rests directly on the ground. Coil heights can be adjusted using inflatable air bladders within the sled, but are typically maintained at the standard height of 40 cm above the ground, equivalent to mounting the coils on their standard wheels. The system is towed by an eight-wheeled Argo all-terrain vehicle. A 16-foot tongue attaches the coil assembly to the Argo and maintains sufficient separation so that the vehicle does not influence the geophysical data. A single Global Positioning System (GPS) sensor is mounted over the center of the two coils to provide real-time positional tracking capabilities. System electronics are securely mounted in the vehicle's rear compartment while the data loggers are located in the driver's compartment to allow continuous monitoring of system function.

(2) The system was designed with the goal of quickly collecting the highest quality geophysical data on a modular, reusable platform. The smooth-bottomed sled allows the system to negotiate rough terrain without the jarring and associated mechanical noise usually found in wheel-mounted systems. Lightweight and durable, the poly-plastic shell is composed of several pieces that can be quickly replaced if field repairs are necessary. In addition, the coils are fully enclosed during operation, allowing the towed array a degree of weatherproofing not usually found in geophysical equipment.

(3) The EM61 is a time-domain electromagnetic instrument designed to detect, with high spatial resolution, shallow ferrous and nonferrous metallic objects. The applicability of the instrument for ordnance and explosives (OE) detection has been widely demonstrated at sites across the United States. Each instrument consists of two air-cored coils (1- by 0.5-m), batteries, processing electronics, and a digital data recorder. The larger of the two coils functions as the electromagnetic (EM) source and receiver and is positioned 40 cm below a second receiver coil. Secondary currents induced in both coils are measured in millivolts (mV).

(4) Geonics has recently updated their standard EM61 system to the EM61 MKII. The primary difference in the MKII system is the use of multiple time-gates; the time after the EM pulse is generated that the receiver coil measures the response. Standard EM61's offer a single time-gate in both the bottom and the top coils. While the top coil time-gate is unchanged, the MKII records early, middle, and late channels from the bottom coil. The late time-gate (third channel) corresponds to the standard EM61 while the earlier time-gates offer enhanced capabilities for the detection of smaller metallic objects. Data from all three channels will be stored and processed during the demonstrations at APG.

b. Single EM61 MKII/man-portable. This system will be employed to survey the calibration lanes, the blind grid, the mogul and the woods scenarios. In an effort to maintain the highest standards for quality data acquisition in an area suspected to have small munitions, the EM61 will be operated in a litter/strecher configuration, where the coils are supported by 12-foot long fiberglass poles and transported by two operators. The data logger and backpack will be controlled by the operator at the back of the system. Coil height, consistent with the towed array at 40 cm, will be maintained through the use of harnesses worn by both operators. NAEVA has found data quality in the tandem configuration to be superior to wheeled operation in all but the smoothest terrain.

Figure 1. Dual EM61 MKII/towed array.

2.1.3 Data Processing Description (provided by demonstrator)

a. All towed array data will be collected with real-time GPS data positioning from an antenna mounted between the two coils. EM data will be collected at a rate of 10 readings per second, which equates to more than one reading per foot. GPS locations will be logged at a rate of one reading per second. Real-time corrections from the GPS base receiver are broadcast to the roving GPS unit via a radio link. The GPS and EM data will be recorded in a single binary file on an Alegro field computer running Geonics' ML61MK2A software. This file is converted to a standard American Standard Code for Information Interchange (ASCII) file using Geonics' Multi61 Mark2 software. To maintain straight line profiling and to minimize the occurrence of gaps within the data, polyvinyl chloride (PVC) pin flags will be used as ground control. The flags will be set in parallel lines across the area of investigation with alternating colors signifying the data collection paths. Pin flags will be spaced 8 feet apart, resulting in one pass with the array every 4 feet. Previous experience has shown that this spacing minimizes the occurrence of gaps between passes as well as providing overlapping coverage of the coil-to-coil gap inherent in the array. Additionally, navigation and real-time field coverage will be aided by the use of StarPal software running on a Panasonic Toughbook computer linked to the GPS.

b. In areas of extremely rough terrain (mogul scenarios and the woods at APG), a single EM61 MKII will be hand-operated by field personnel. Data will be collected at a rate of 10 readings per second along lines spaced 2 feet apart. Raw binary data is collected on an Alegro portable field computer using EM61 MKIIA Software. This file is converted to a standard ASCII file using Geonics' DAT61 MKII software.

c. Whether operating the towed array or the hand-operated system, all geophysical mapping in open areas will make use of real-time GPS data positioning. In the case of the towed array, the rover antenna will be mounted between the two coils and an offset will be applied during the post-processing to produce the actual coil positions. The rover antenna can be mounted directly over the single coil in hand-operated mode so that no offset is necessary.

d. In areas where GPS satellite coverage is inadequate, such as the wooded scenario at APG, NAEVA will utilize tape measures and painted ropes to maintain accurate data positioning. Tape measures will be used with the existing control points to create a series of square grids to cover the area. Painted ropes will be placed every 25 feet, perpendicular to the direction of data collection. Evenly spaced, painted marks on the ropes will allow the data collection team to maintain straight-line profiling over the area of investigation. Once all the data is collected, the control points will be used to transform the data from local coordinates to Geodetic Coordinates for scoring submittal. NAEVA has successfully used this method at numerous UXO sites where GPS coverage is not available.

Data Processing.

a. The geophysical data will be temporarily stored in the instrument logger during data collection and then downloaded into a laptop computer for on-site review and editing. Using Geosoft's Oasis Montaj software, a track plot of the instrument's GPS positions will be created to ensure that adequate data coverage has been achieved. For those areas without GPS coverage, Geonics' DAT61 MKII software will be employed to correct the EM61 positioning using the fiducial marks entered in the data. Preliminary contour maps will then be created for field review of each survey area. Once in-field processing and review is completed, the data will be electronically transferred to NAEVA's Virginia office for analysis/target selection.

b. Geosoft's Oasis Montaj UXO software package will be employed to post-process and contour the raw data, and to identify potential UXO targets. The program identifies peak amplitude responses of the frequency associated with, but not limited to, UXO items. Anomalies may generate multiple target designations depending on individual signature characteristics.

c. Geophysical data processing includes the following:

(1) Instrument drift correction (leveling).

(2) Lag correction.

(3) Digital filtering and enhancement (if necessary).

(4) Gridding of data.

(5) Selection of all anomalies.

(6) Selection of targets for intrusive characterization.

(7) Preparation of geophysical and target maps.

d. Once NAEVA has completed the steps described above, the data will be forwarded to the subcontractor, AETC, for discrimination processing and final dig list development. AETC will only evaluate targets selected by NAEVA Geophysics. The first step will be to invert the measured EM61 MKII data using a three-axis dipole model. AETC's EM61 fit algorithm determines the best set of induced dipole model parameters that account for the spatial variation of the EM61 signal as the sensor is moved over the object. The model parameters are target X,Y location and depth, three dipole response coefficients corresponding to the principle axes of the target, and the three angles that describe the orientation of the target. There is a set of three response coefficients for each of the EM61 MKII's four time-gates. The magnitude of the response coefficients scales with the size of the target. An empirical relationship will be used to translate the sum of the target response coefficients into an equivalent UXO caliber. The relationship between the three response coefficients tells us something about target shape. Cylindrical objects like most UXO have one large coefficient and two smaller, equal coefficients. Plate-like objects nominally have two large and one small coefficient.

e. Under controlled measurements, both the forward dipole model and fit algorithm have been found to be highly effective in describing EM61 measurements over buried ordnance. The accuracy of the fit algorithm has been found to be limited by poor quality data. In particular, closely spaced and accurately positioned measurements by the EM61 sensor are important for good fit results. Also, the model only describes the EM61 signal from compact objects and does not apply to extended objects such as utility lines.

2.1.4 Data Submission Format

Data were submitted for scoring in accordance with data submission protocols outlined in the Standardized UXO Technology Demonstration Site Handbook. These submitted data are not included in this report in order to protect GT information.

2.1.5 Demonstrator Quality Assurance (QA) and Quality Control (QC) (provided by demonstrator)

Overview of Quality Control (QC).

a. To establish confidence in the data reliability, tests will be conducted in a systematic manner throughout the duration of the fieldwork. Various types of quality control data are generated prior to, during, and after all data collection sessions.

b. Daily. A location identified as having no subsurface metal will be designated as a calibration point. Readings will be collected in a stationary position over the calibration point to ensure a stable and repeatable response was exhibited. During this time, a metallic item will be placed in a standard position with respect to the coils, and the instrument's response will be observed. The item will then be removed, and static readings continued. This test is performed daily to establish that the instrument is functioning properly, as indicated by a stable and repeatable response. The calibration point will also document the continued accurate performance of the GPS equipment.

c. A second location will be established over a buried item of known response, likely within one of the calibration lanes. At the start and end of each field day, two lines will be collected bidirectionally across the item along the same survey line. The data will then be reviewed for consistent response, positioning, and to determine an appropriate lag correction.

d. During Data Collection. Upon completion of the original collection of a data set, approximately 3 percent of the line footage for each surveyed area will be recollected as a check of instrument repeatability and positioning. The repeat lines will be saved to separate files and used to create profiles that provide direct comparison with the original data. Each profile will be evaluated for repeatability in both instrument response and data positioning.

Overview of Quality Assurance (QA).

a. For purposes of this investigation, QA is defined as the procedures to be employed during the demonstration. All of the procedures are designed to provide excellent data quality while maximizing production during the field efforts.

b. All towed array data will be collected with real-time GPS data positioning from an antenna mounted between the two coils. EM data will be collected at a rate of 10 readings per second which equates to more than one reading per foot. GPS locations will be logged at a rate of one reading per second. To maintain straight line profiling and to minimize the occurrence of gaps within the data, PVC pin flags will be used as ground control. The flags will be set in parallel lines across the area of investigation with alternating colors signifying the data collection paths. Pin flags will be spaced 8 feet apart, resulting in one pass with the array every 4 feet. Previous experience has shown that this spacing minimizes the occurrence of gaps between passes as well as providing overlapping coverage of the coil-to-coil gap inherent in the array. While the GPS has a listed accuracy of 3 cm, the expected accuracy of resultant target selections is signified by a circle with a 1-foot radius around each target.

c. NAEVA's hand-operated system will use GPS for data positioning in areas such as the mogul challenge where satellite coverage is available. In such areas the data collection procedures will be identical to those described above with the exception that the line spacing will be reduced to 2 feet. NAEVA does not expect to be able to maintain satellite coverage in the wooded area at APG. Tape measures will be used in conjunction with the established control points to create a series of square survey cells to completely cover the area of investigation. Within each survey cell, data collection will be controlled using a series of marked survey ropes positioned at 25-foot intervals perpendicular to the survey line direction. Alternating color codes painted on the ropes at 2-foot intervals facilitate straight line profiling with the instrumentation during data collection. Additionally, the ropes will serve as a point where the operator manually enters marks, or fiducials, into the data stream. The data is then repositioned between the fiducials to account for the changes in velocity that occur as the instrument is carried across variable terrain conditions (i.e. slope, deadfall, vines, etc.). The inconsistent and difficult terrain expected at the site dictate this relatively short fiducial separation (25 ft) to accommodate changes in velocity where greater care is necessary to navigate the instrument safely and effectively across the site.

2.1.6 Additional Records

The following record(s) by this vendor can be accessed via the Internet as MicroSoft Word documents at www.uxotestsites.org.

2.2 APG SITE INFORMATION

2.2.1 Location

The APG Active Response Demonstration Site is located within a secured range area of the Aberdeen Area. The Aberdeen Area of APG is located approximately 30 miles northeast of Baltimore at the northern end of the Chesapeake Bay. The Active Response Demonstration Site encompasses 1.98 acres of upland and lowland flats.

2.2.2 Soil Type

According to the soils survey conducted for the entire area of APG in 1998, the test site consists primarily of Elkton Series type soil (ref 2). The Elkton Series consist of very deep, slowly permeable, poorly drained soils. These soils formed in silty aeolin sediments and the underlying loamy alluvial and marine sediments. They are on upland and lowland flats and in depressions of the Mid-Atlantic Coastal Plain. Slopes range from 0 to 2 percent.

ERDC conducted a site-specific analysis in May of 2002 (ref 3). The results basically matched the soil survey mentioned above. Seventy percent of the samples taken were classified as silty loam. The majority (77 percent) of the soil samples had a measured water content between 15 and 30 percent, with the water content decreasing slightly with depth.

For more details concerning the soil properties at the APG test site, go to www.uxotestsites.org on the web to view the entire soils description report.

SECTION 3. FIELD DATA

3.1 DATE OF FIELD ACTIVITIES (9 and 20 through 22 August 2004)

3.2 AREAS TESTED/NUMBER OF HOURS

Areas tested and total number of hours operated at each site are presented in Table 1.

TABLE 1. AREAS TESTED AND NUMBER OF HOURS

Area	Number of Hours
Calibration lanes	4.00
Active site	8.08

3.3 TEST CONDITIONS

3.3.1 Weather Conditions

An APG weather station located approximately one mile west of the test site was used to record average temperature and precipitation on a half-hour basis for each day of operation. The temperatures presented in Table 2 represent the average temperature during field operations from 0700 to 1700 hours while precipitation data represents a daily total amount of rainfall. Hourly weather logs used to generate this summary are provided in Appendix B.

TABLE 2. TEMPERATURE/PRECIPITATION DATA SUMMARY

Date, 2004	Average Temperature, ^{o}F	Total Daily Precipitation, in.
09 August	78.4	0.00
20 August	85.6	0.00
21 August	79.2	0.09
22 August	72.0	0.00

3.3.2 Field Conditions

NAEVA surveyed the active site on 20 and 21 August 2004. The field was dry and the weather warm throughout the survey.

3.3.3 Soil Moisture

Three soil probes were placed at various locations within the site to capture soil moisture data: blind grid, calibration, mogul, and wooded areas. Measurements were collected in percent moisture and were taken twice daily (morning and afternoon) from five different soil depths (1 to 6 in., 6 to 12 in., 12 to 24 in., 24 to 36 in., and 36 to 48 in.) from each probe. Soil moisture logs are provided in Appendix C.

3.4 FIELD ACTIVITIES

3.4.1 Setup/Mobilization

These activities included initial mobilization and daily equipment preparation and break down. A 4-person crew took 1 hour and 50 minutes to perform the initial setup and mobilization. There was 40 minutes of daily equipment preparation and end of the day equipment break down lasted 40 minutes.

3.4.2 Calibration

NAEVA spent a total of 4 hours in the calibration lanes, of which 1 hour and 40 minutes was spent collecting data. Calibration exercises during survey of the active site totaled 1 hour and 5 minutes.

3.4.3 Downtime Occasions

Occasions of downtime are grouped into five categories: equipment/data checks or equipment maintenance, equipment failure and repair, weather, demonstration site issues, or breaks/lunch. All downtime is included for the purposes of calculating labor costs (section 5) except for downtime due to demonstration site issues. Demonstration site issues, while noted in the daily log, are considered nonchargeable downtime for the purposes of calculating labor costs and are not discussed. Breaks and lunches are discussed in this section and billed to the total site survey area.

3.4.3.1 Equipment/data checks, maintenance. Equipment data checks and maintenance activities accounted for no site usage time. These activities included changing out batteries and routine data checks to ensure the data was being properly recorded/collected. NAEVA spent an additional 1 hour and 55 minutes for breaks and lunches.

3.4.3.2 Equipment failure or repair. No time was needed to resolve equipment failures that occurred while surveying the Active Response area.

3.4.3.3 Weather. No weather delays occurred during the survey. NAEVA did get shut down for a total of 1 hour due to firing on adjacent ranges.

3.4.4 Data Collection

NAEVA spent a total time of 8 hours and 5 minutes in the Active Response area, 3 hours and 50 minutes of which was spent collecting data.

3.4.5 Demobilization

The NAEVA survey crew went on to conduct a full demonstration of the site. Therefore, demobilization did not occur until August 22, 2004. On that day, it took the crew 1 hour and 35 minutes to break down and pack up their equipment.

3.5 PROCESSING TIME

NAEVA submitted the raw data from the demonstration activities on the last day of the demonstration, as required. The scoring submittal data was also provided within the required 30-day timeframe.

3.6 DEMONSTRATOR'S FIELD PERSONNEL

Leif Riddervold
Alexander Kostera
Ashley Mowery
David Garey

3.7 DEMONSTRATOR'S FIELD SURVEYING METHOD

NAEVA surveyed the active site in a linear manner. NAEVA used the width of the array for the distance of line spacing.

3.8 SUMMARY OF DAILY LOGS

Daily logs capture all field activities during this demonstration and are provided in Appendix D. Activities pertinent to this specific demonstration are indicated in highlighted text.

SECTION 4. TECHNICAL PERFORMANCE RESULTS

4.1 ROC CURVES USING ALL ORDNANCE CATEGORIES

The probability of detection for the response stage (P_d^{res}) and the discrimination stage (P_d^{disc}) versus their respective probability of false positive (P_{fp}) are shown in Figure 2. Both probabilities plotted against their respective BAR are shown in Figure 3, and both figures use horizontal lines to illustrate the performance of the demonstrator at two demonstrator-specified points: at the system noise level for the response stage, representing the point below which targets are not considered detectable, and at the demonstrator's recommended threshold level for the discrimination stage, defining the subset of targets the demonstrator would recommend digging based on discrimination.

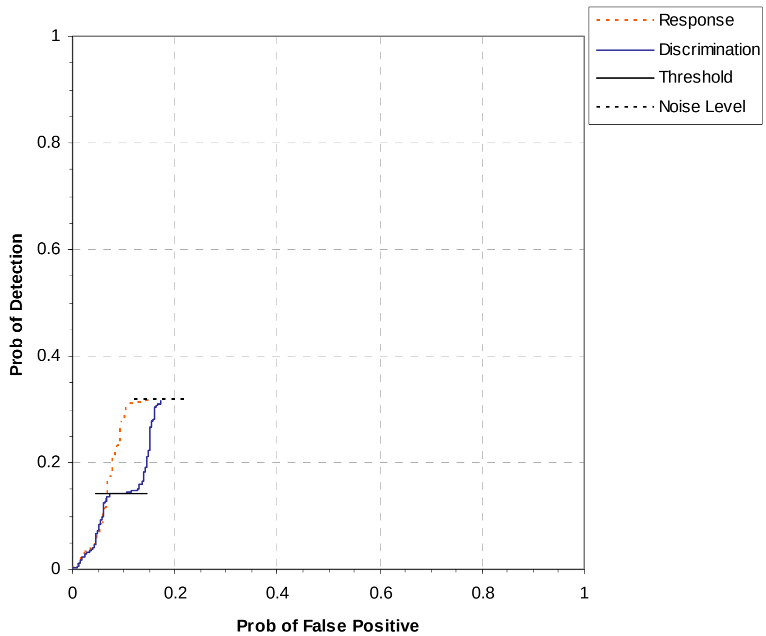

Figure 2. EM61 MKII/TOWED active response P_d^{res} and P_d^{disc} versus their respective P_{fp} over all ordnance categories combined.

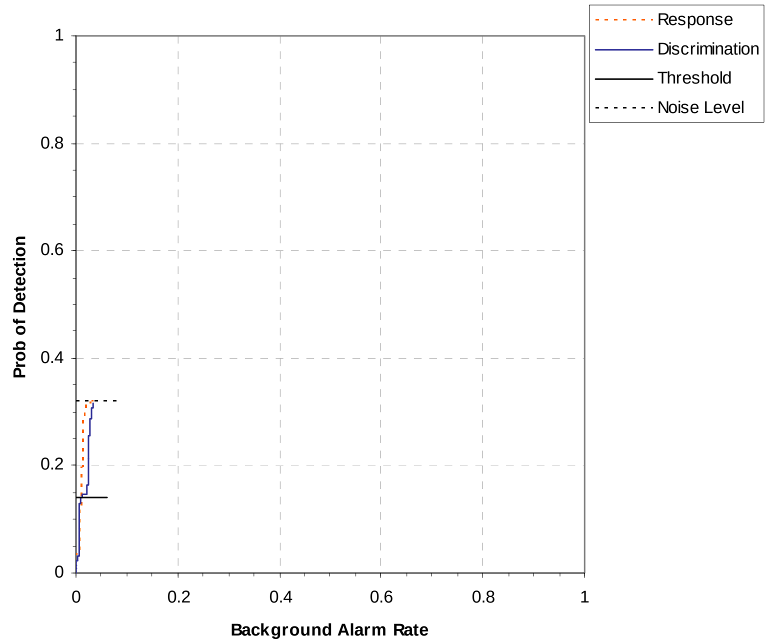

Figure 3. EM61 MKII/TOWED active response P_d^{res} and P_d^{disc} versus their respective BAR over all ordnance categories combined.

4.2 PERFORMANCE SUMMARIES

The response stage results are derived from the list of anomalies above the demonstrator-provided noise level. The results for the discrimination stage are derived from the demonstrator's recommended threshold for optimizing UXO field cleanup by minimizing false digs and maximizing ordnance recovery. The lower 90-percent confidence limit on P_d and P_{fp} was calculated assuming that the number of detections and false positives are binomially distributed random variables.

Results for the active response test are presented in Table 3 (cost results are provided in section 5).

TABLE 3. SUMMARY OF ACTIVE SITE RESULTS FOR EM61 MKII/TOWED

Metric	Overall
RESPONSE STAGE	
P_d	0.32
P_d Low 90% conf	0.29
P_d Upper 90% conf	0.35
P_{fp}	0.17
P_{fp} Low 90% conf	0.16
P_{fp} Upper 90% conf	0.19
BAR	0.03
DISCRIMINATION STAGE	
P_d	0.14
P_d Low 90% conf	0.12
P_d Upper 90% conf	0.17
P_{fp}	0.10
P_{fp} Low 90% conf	0.08
P_{fp} Upper 90% conf	0.11
BAR	0.01

A comparison of the P_d, P_{fp}, and P_{ba}/BAR for both the Response Stage and Discrimination Stage for the Blind Grid, the Open Field, and the Active Site is presented in Table 4. The P_d^{res} versus the respective P_{fp} over all ordnance categories is shown in Figure 4. The P_d^{disc} versus their respective P_{fp} over all ordnance categories are shown in Figure 5. Horizontal lines are used in Figure 5 to illustrate the performance of the demonstrator at the recommended discrimination threshold levels, defining the subset of targets the demonstrator would recommend digging based on discrimination.

TABLE 4. COMPARISON OF BLIND GRID, OPEN FIELD, AND ACTIVE SITE RESULTS FOR EM61 MKII/TOWED

Blind Grid		**Open Field**		**Active Site**	
Response Stage		***Response Stage***		***Response Stage***	
P_d	0.92	P_d	0.66	P_d	0.32
P_{fp}	0.86	P_{fp}	0.47	P_{fp}	0.17
P_{ba}	0.19	BAR	0.17	BAR	0.03
Discrimination Stage		***Discrimination Stage***		***Discrimination Stage***	
P_d	0.39	P_d	0.42	P_d	0.14
P_{fp}	0.48	P_{fp}	0.37	P_{fp}	0.10
P_{ba}	0.05	BAR	0.02	BAR	0.01

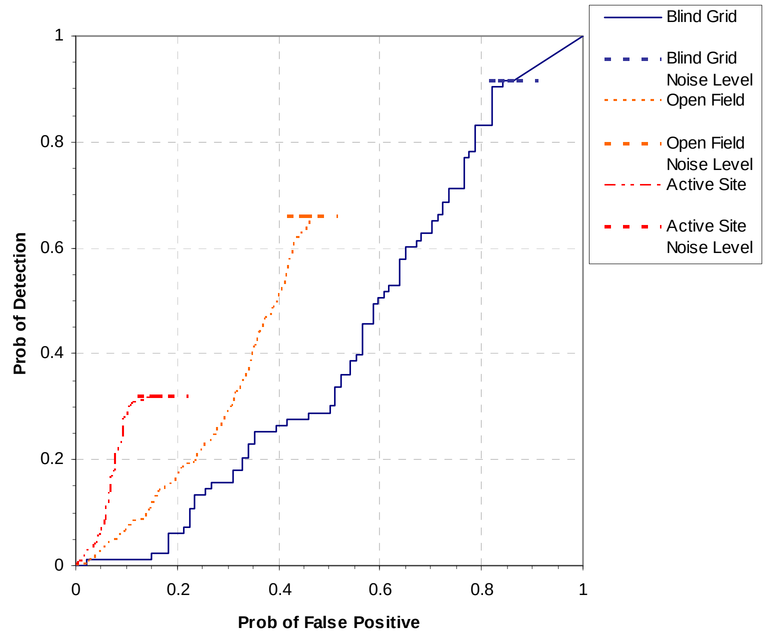

Figure 4. EM61 MKII/TOWED P_d^{res} stages versus the respective P_{fp} over all ordnance categories combined.

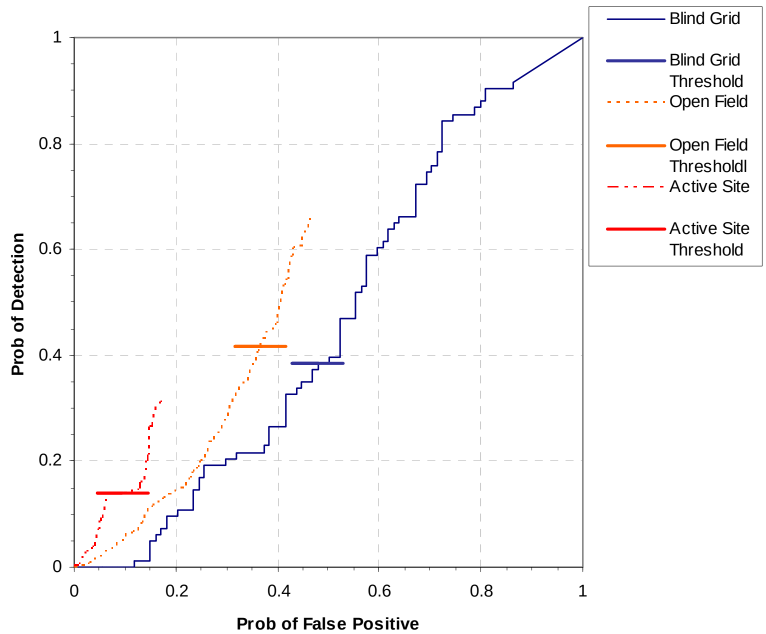

Figure 5. EM61 MKII/TOWED P_d^{disc} versus the respective P_{fp} over all ordnance categories combined.

4.3 EFFICIENCY, REJECTION RATES, AND TYPE CLASSIFICATION

Efficiency and rejection rates are calculated to quantify the discrimination ability at specific points of interest on the ROC curve: (1) at the point where no decrease in P_d is suffered (i.e., the efficiency is by definition equal to one) and (2) at the operator selected threshold. These values are presented in Table 5.

TABLE 5. EFFICIENCY AND REJECTION RATES

	Efficiency (E)	False Positive Rejection Rate	Background Alarm Rejection Rate
At operating point	0.44	0.44	0.69
With no loss of P_d	1.00	0.00	0.00

4.4 LOCATION ACCURACY

The mean location error and standard deviations are presented in Table 6. These calculations are based on average missed depth for ordnance correctly identified in the discrimination stage. Depths could not be accurately measured since the discovered ordnance and clutter were discovered and not emplaced. For the active response, no depth errors are calculated and (X, Y) positions are known from the recovery operation.

TABLE 6. MEAN LOCATION ERROR AND STANDARD DEVIATION (m)

	Mean	Standard Deviation
Northing	0.10	0.22
Easting	0.04	0.17

4.5 STATISTICAL COMPARISONS

Statistical chi-square significance tests were used to compare results between the blind grid and active site and the open field and active site scenarios. The intent of the blind grid and active site comparison is to determine if the feature introduced in each scenario has a degrading effect on the performance of the sensor system. The intent of the open field and active site comparison is to determine if the feature introduced in each scenario has any effect, whether a degradation or an improvement, on the performance of the sensor system. However, any modifications in the UXO sensor system during the test, like changes in the processing or changes in the selection of the operating threshold, will also contribute to performance differences.

The chi-square test for comparison between ratios was used at a significance level of 0.05 to compare blind grid to open field with regard to P_d^{res}, P_d^{disc}, P_{fp}^{res}, and P_{fp}^{disc}, efficiency and rejection rate. These results are presented in Table 7 and Table 8 for the blind grid versus active site and the open field versus active site comparisons, respectively. A detailed explanation and example of the chi-square application is provided in Appendix A.

TABLE 7. CHI-SQUARE RESULTS - BLIND GRID VERSUS ACTIVE SITE

Metric	Overall
P_d^{res}	Significant
P_d^{disc}	Significant
P_{fp}^{res}	Significant
P_{fp}^{disc}	Significant
Efficiency	Not Significant
Rejection rate	Not Significant

TABLE 8. CHI-SQUARE RESULTS - OPEN FIELD VERSUS ACTIVE SITE

Metric	Overall
P_d^{res}	Significant
P_d^{disc}	Significant
P_{fp}^{res}	Significant
P_{fp}^{disc}	Significant
Efficiency	Significant
Rejection rate	Significant

SECTION 5. ON-SITE LABOR COSTS

A standardized estimate for labor costs associated with this effort was calculated as follows: the first person at the test site was designated supervisor, the second person was designated data analyst, and the third and following personnel were considered field support. Standardized hourly labor rates were charged by title: supervisor at $95.00/hour, data analyst at $57.00/hour, and field support at $28.50/hour.

Government representatives monitored on-site activity. All on-site activities were grouped into one of ten categories: initial setup/mobilization, daily setup/stop, calibration, collecting data, downtime due to break/lunch, downtime due to equipment failure, downtime due to equipment/data checks or maintenance, downtime due to weather, downtime due to demonstration site issue, or demobilization. The daily activity log is provided in Appendix D. A summary of field activities is provided in Section 3.4.

The standardized cost estimate associated with the labor needed to perform the field activities is presented in Table 9. Note that calibration time includes time spent in the calibration lanes as well as field calibrations. Site survey time includes daily setup/stop time, collecting data, breaks/lunch, downtime due to equipment/data checks or maintenance, downtime due to failure, and downtime due to weather.

TABLE 9. ON-SITE LABOR COSTS

	No. People	Hourly Wage	Hours	Cost
Initial Setup				
Supervisor	1	$95.00	1.83	$173.85
Data analyst	1	57.00	1.83	104.31
Field support	2	28.50	1.83	104.31
Subtotal				**$382.47**
Calibration				
Supervisor	1	$95.00	5.08	$482.60
Data analyst	1	57.00	5.08	289.56
Field support	2	28.50	5.08	289.56
Subtotal				**$1061.72**
Site Survey				
Supervisor	1	$95.00	8.08	$767.60
Data analyst	1	57.00	8.08	460.56
Field support	0	28.50	0.00	0.00
Subtotal				**$1228.16**

See notes at end of table.

TABLE 9 (CONT'D)

	No. People	Hourly Wage	Hours	Cost
Demobilization				
Supervisor	1	$95.00	1.58	$150.10
Data analyst	1	57.00	1.58	90.06
Field support	0	28.50	0.00	0.00
Subtotal				**$240.16**
Total				**$2912.51**

Notes: Calibration time includes time spent in the calibration lanes as well as calibration before each data run.
Site survey time includes daily setup/stop time, collecting data, breaks/lunch, downtime due to system maintenance, failure, and weather.

SECTION 6. APPENDIXES

APPENDIX A. TERMS AND DEFINITIONS

GENERAL DEFINITIONS

Anomaly: Location of a system response deemed to warrant further investigation by the demonstrator for consideration as an emplaced ordnance item.

Detection: An anomaly location that is within R_{halo} of an emplaced ordnance item.

Munitions and Explosives Of Concern (MEC): Specific categories of military munitions that may pose unique explosive safety risks, including UXO as defined in 10 USC 101(e)(5), DMM as defined in 10 USC 2710(e)(2) and/or munitions constituents (e.g., TNT, RDX) as defined in 10 USC 2710(e)(3) that are present in high enough concentrations to pose an explosive hazard.

Emplaced Ordnance: An ordnance item buried by the government at a specified location in the test site (for the Active site all 'emplaced' items are items discovered during recovery operations and are not strictly emplaced items).

Emplaced Clutter: A clutter item (i.e., non-ordnance item) buried by the government at a specified location in the test site (for the Active site all 'emplaced' items are items discovered during recovery operations and are not strictly emplaced items).

R_{halo}: A pre-determined radius about the periphery of an emplaced item (clutter or ordnance) within which a location identified by the demonstrator as being of interest is considered to be a response from that item. If multiple declarations lie within R_{halo} of any item (clutter or ordnance), the declaration with the highest signal output within the R_{halo} will be utilized. For the purpose of this program, a circular halo 0.5 meters in radius will be placed around the center of the object for all clutter and ordnance items.

Response Stage Noise Level: The level that represents the point below which anomalies are not considered detectable. Demonstrators are required to provide the recommended noise level for the Blind Grid test area.

Discrimination Stage Threshold: The demonstrator selected threshold level that they believe provides optimum performance of the system by retaining all detectable ordnance and rejecting the maximum amount of clutter. This level defines the subset of anomalies the demonstrator would recommend digging based on discrimination.

Binomially Distributed Random Variable: A random variable of the type which has only two possible outcomes, say success and failure, is repeated for n independent trials with the probability p of success and the probability 1-p of failure being the same for each trial. The number of successes x observed in the n trials is an estimate of p and is considered to be a binomially distributed random variable.

RESPONSE AND DISCRIMINATION STAGE DATA

The scoring of the demonstrator's performance is conducted in two stages. These two stages are termed the response stage and discrimination stage. For both stages, the probability of detection (P_d) and the false alarms are reported as receiver operating characteristic (ROC) curves. False alarms are divided into those anomalies that correspond to emplaced clutter items, measuring the probability of false positive (P_{fp}) and those that do not correspond to any known item, termed background alarms.

The response stage scoring evaluates the ability of the system to detect emplaced targets without regard to ability to discriminate ordnance from other anomalies. For the response stage, the demonstrator provides the scoring committee with the location and signal strength of all anomalies that the demonstrator has deemed sufficient to warrant further investigation and/or processing as potential emplaced ordnance items. This list is generated with minimal processing (e.g., this list will include all signals above the system noise threshold). As such, it represents the most inclusive list of anomalies.

The discrimination stage evaluates the demonstrator's ability to correctly identify ordnance as such, and to reject clutter. For the same locations as in the response stage anomaly list, the discrimination stage list contains the output of the algorithms applied in the discrimination stage processing. This list is prioritized based on the demonstrator's determination that an anomaly location is likely to contain ordnance. Thus, higher output values are indicative of higher confidence that an ordnance item is present at the specified location. For electronic signal processing, priority ranking is based on algorithm output. For other systems, priority ranking is based on human judgment. The demonstrator also selects the threshold that the demonstrator believes will provide optimum system performance, (i.e., that retains all the detected ordnance and rejects the maximum amount of clutter).

Note: The two lists provided by the demonstrator contain identical numbers of potential target locations. They differ only in the priority ranking of the declarations.

RESPONSE STAGE DEFINITIONS

Response Stage Probability of Detection (P_d^{res}): P_d^{res} = (No. of response-stage detections)/ (No. of emplaced ordnance in the test site).

Response Stage False Positive (fp^{res}): An anomaly location that is within R_{halo} of an emplaced clutter item.

Response Stage Probability of False Positive (P_{fp}^{res}): P_{fp}^{res} = (No. of response-stage false positives)/(No. of emplaced clutter items).

Response Stage Background Alarm (ba^{res}): An anomaly in a blind grid cell that contains neither emplaced ordnance nor an emplaced clutter item. An anomaly location in the open field or scenarios that is outside R_{halo} of any emplaced ordnance or emplaced clutter item.

Response Stage Probability of Background Alarm (P_{ba}^{res}): Blind grid only: P_{ba}^{res} = (No. of response-stage background alarms)/(No. of empty grid locations).

Response Stage Background Alarm Rate (BAR^{res}): Open field only: BAR^{res} = (No. of response-stage background alarms)/(arbitrary constant).

Note: The quantities P_d^{res}, P_{fp}^{res}, P_{ba}^{res}, and BAR^{res} are functions of t^{res}, the threshold applied to the response-stage signal strength. These quantities can therefore be written as $P_d^{res}(t^{res})$, $P_{fp}^{res}(t^{res})$, $P_{ba}^{res}(t^{res})$, and $BAR^{res}(t^{res})$.

DISCRIMINATION STAGE DEFINITIONS

Discrimination: The application of a signal processing algorithm or human judgment to response-stage data that discriminates ordnance from clutter. Discrimination should identify anomalies that the demonstrator has high confidence correspond to ordnance, as well as those that the demonstrator has high confidence correspond to nonordnance or background returns. The former should be ranked with highest priority and the latter with lowest.

Discrimination Stage Probability of Detection (P_d^{disc}): P_d^{disc} = (No. of discrimination-stage detections)/(No. of emplaced ordnance in the test site).

Discrimination Stage False Positive (fp^{disc}): An anomaly location that is within R_{halo} of an emplaced clutter item.

Discrimination Stage Probability of False Positive (P_{fp}^{disc}): P_{fp}^{disc} = (No. of discrimination stage false positives)/(No. of emplaced clutter items).

Discrimination Stage Background Alarm (ba^{disc}): An anomaly in a blind grid cell that contains neither emplaced ordnance nor an emplaced clutter item. An anomaly location in the open field or scenarios that is outside R_{halo} of any emplaced ordnance or emplaced clutter item.

Discrimination Stage Probability of Background Alarm (P_{ba}^{disc}): P_{ba}^{disc} = (No. of discrimination-stage background alarms)/(No. of empty grid locations).

Discrimination Stage Background Alarm Rate (BAR^{disc}): BAR^{disc} = (No. of discrimination-stage background alarms)/(arbitrary constant).

Note that the quantities P_d^{disc}, P_{fp}^{disc}, P_{ba}^{disc}, and BAR^{disc} are functions of t^{disc}, the threshold applied to the discrimination-stage signal strength. These quantities can therefore be written as $P_d^{disc}(t^{disc})$, $P_{fp}^{disc}(t^{disc})$, $P_{ba}^{disc}(t^{disc})$, and $BAR^{disc}(t^{disc})$.

RECEIVER-OPERATING CHARACERISTIC (ROC) CURVES

ROC curves at both the response and discrimination stages can be constructed based on the above definitions. The ROC curves plot the relationship between P_d versus P_{fp} and P_d versus BAR or P_{ba} as the threshold applied to the signal strength is varied from its minimum (t_{min}) to its maximum (t_{max}) value.[1] Figure A-1 shows how P_d versus P_{fp} and P_d versus BAR are combined into ROC curves. Note that the "res" and "disc" superscripts have been suppressed from all the variables for clarity.

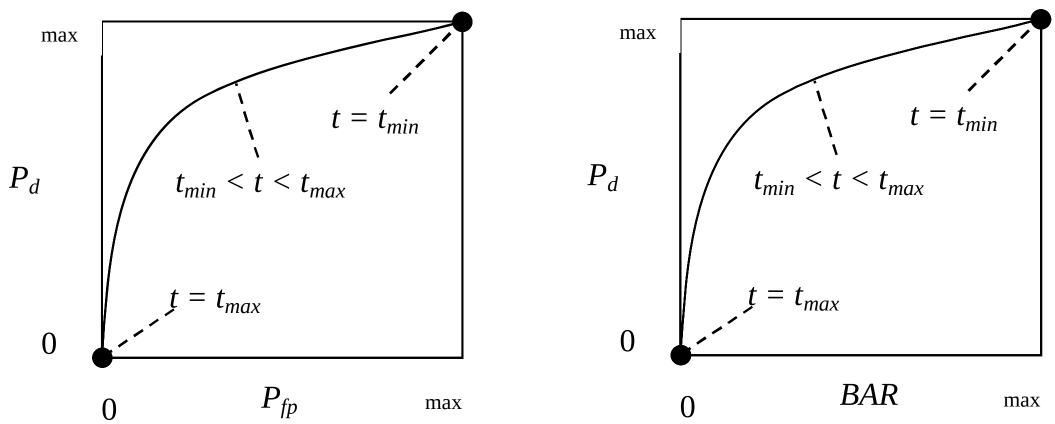

Figure A-1. ROC curves for open field testing. Each curve applies to both the response and discrimination stages.

METRICS TO CHARACTERIZE THE DISCRIMINATION STAGE

The demonstrator is also scored on efficiency and rejection ratio, which measure the effectiveness of the discrimination stage processing. The goal of discrimination is to retain the greatest number of ordnance detections from the anomaly list, while rejecting the maximum number of anomalies arising from nonordnance items. The efficiency measures the amount of detected ordnance retained by the discrimination, while the rejection ratio measures the fraction of false alarms rejected. Both measures are defined relative to the entire response list, i.e., the maximum ordnance detectable by the sensor and its accompanying false positive rate or background alarm rate.

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[1]Strictly speaking, ROC curves plot the P_d versus P_{ba} over a pre-determined and fixed number of detection opportunities (some of the opportunities are located over ordnance and others are located over clutter or blank spots). In an open field scenario, each system suppresses its signal strength reports until some bare-minimum signal response is received by the system. Consequently, the open field ROC curves do not have information from low signal-output locations, and, furthermore, different contractors report their signals over a different set of locations on the ground. These ROC curves are thus not true to the strict definition of ROC curves as defined in textbooks on detection theory. Note, however, that the ROC curves obtained in the blind grid test sites are true ROC curves.

Efficiency (E): $E = P_d^{disc}(t^{disc})/P_d^{res}(t_{min}^{res})$; Measures (at a threshold of interest), the degree to which the maximum theoretical detection performance of the sensor system (as determined by the response stage ^{t}min) is preserved after application of discrimination techniques. Efficiency is a number between 0 and 1. An efficiency of 1 implies that all of the ordnance initially detected in the response stage was retained at the specified threshold in the discrimination stage, t^{disc}.

False Positive Rejection Rate (R_{fp}): $R_{fp} = 1 - [P_{fp}^{disc}(t^{disc})/P_{fp}^{res}(t_{min}^{res})]$; Measures (at a threshold of interest), the degree to which the sensor system's false positive performance is improved over the maximum false positive performance (as determined by the response stage ^{t}min). The rejection rate is a number between 0 and 1. A rejection rate of 1 implies that all emplaced clutter initially detected in the response stage were correctly rejected at the specified threshold in the discrimination stage.

Background Alarm Rejection Rate (R_{ba}):

Blind grid: $R_{ba} = 1 - [P_{ba}^{disc}(t^{disc})/P_{ba}^{res}(t_{min}^{res})]$.
Open field: $R_{ba} = 1 - [BAR^{disc}(t^{disc})/BAR^{res}(t_{min}^{res})])$.

Measures the degree to which the discrimination stage correctly rejects background alarms initially detected in the response stage. The rejection rate is a number between 0 and 1. A rejection rate of 1 implies that all background alarms initially detected in the response stage were rejected at the specified threshold in the discrimination stage.

CHI-SQUARE COMPARISON EXPLANATION:

The chi-square test for differences in probabilities (or 2 by 2 contingency table) is used to analyze two samples drawn from two different populations to see if both populations have the same or different proportions of elements in a certain category. More specifically, two random samples are drawn, one from each population, to test the null hypothesis that the probability of event A (some specified event) is the same for both populations (ref 3).

A 2 by 2 contingency table is used in the Standardized UXO Technology Demonstration Site Program to determine if there is reason to believe that the proportion of ordnance correctly detected/discriminated by demonstrator X’s system is significantly degraded by the more challenging terrain feature introduced. The test statistic of the 2 by 2 contingency table is the chi-square distribution with one degree of freedom. Since an association between the more challenging terrain feature and relatively degraded performance is sought for the blind grid versus active site comparison, a one-sided test is performed. A significance level of 0.05 is chosen which sets a critical decision limit of 2.71 from the chi-square distribution with one degree of freedom. For the open field versus active site comparison, there is no assumption of a degraded performance for either site. Therefore, a two-sided test is performed to test for a significant difference in performance in either direction. Using the same significance level of 0.05, the critical decision limit is set to 3.84 from the chi-square distribution with one degree of freedom. For both tests, the value obtained from the chi-square distribution is a critical decision limit because if the test statistic calculated from the data exceeds this value, the two proportions tested will be considered significantly different. If the test statistic calculated from the data is less than this value, the two proportions tested will be considered not significantly different.

An exception must be applied when either a 0 or 100 percent success rate occurs in the sample data. The chi-square test cannot be used in these instances. Instead, Fischer's test is used and the critical decision limit for one-sided tests is the chosen significance level, which in this case is 0.05. With Fischer's test, if the test statistic is less than the critical value, the proportions are considered to be significantly different.

Standardized UXO Technology Demonstration Site examples, where blind grid results are compared to those from the open field and open field results are compared to those from one of the scenarios, follow. It should be noted that a significant result does not prove a cause and effect relationship exists between the two populations of interest; however, it does serve as a tool to indicate that one data set has experienced a degradation in system performance at a large enough level than can be accounted for merely by chance or random variation. Note also that a result that is not significant indicates that there is not enough evidence to declare that anything more than chance or random variation within the same population is at work between the two data sets being compared.

Demonstrator X achieves the following overall results after surveying each of the three progressively more difficult areas using the same system (results indicate the number of ordnance detected divided by the number of ordnance emplaced):

	Blind grid	Open field	Moguls
P_d^{res}	100/100 = 1.0	8/10 = .80	20/33 = .61
P_d^{disc}	80/100 = 0.80	6/10 = .60	8/33 = .24

P_d^{res}: blind grid versus open field. Using the example data above to compare probabilities of detection in the response stage, all 100 ordnance out of 100 emplaced ordnance items were detected in the blind grid while 8 ordnance out of 10 emplaced were detected in the open field. Fischer's test must be used since a 100 percent success rate occurs in the data. Fischer's test uses the four input values to calculate a test statistic of 0.0075 that is compared against the critical value of 0.05. Since the test statistic is less than the critical value, the smaller response stage detection rate (0.80) is considered to be significantly less at the 0.05 level of significance. While a significant result does not prove a cause and effect relationship exists between the change in survey area and degradation in performance, it does indicate that the detection ability of demonstrator X's system seems to have been degraded in the open field relative to results from the blind grid using the same system.

P_d^{disc}: blind grid versus open field. Using the example data above to compare probabilities of detection in the discrimination stage, 80 out of 100 emplaced ordnance items were correctly discriminated as ordnance in blind grid testing while 6 ordnance out of 10 emplaced were correctly discriminated as such in open field-testing. Those four values are used to calculate a test statistic of 1.12. Since the test statistic is less than the critical value of 2.71, the two discrimination stage detection rates are considered to be not significantly different at the 0.05 level of significance.

P_d^{res}: open field versus moguls. Using the example data above to compare probabilities of detection in the response stage, 8 out of 10 and 20 out of 33 are used to calculate a test statistic of 0.56. Since the test statistic is less than the critical value of 2.71, the two response stage detection rates are considered to be not significantly different at the 0.05 level of significance.

P_d^{disc}: open field versus moguls. Using the example data above to compare probabilities of detection in the discrimination stage, 6 out of 10 and 8 out of 33 are used to calculate a test statistic of 2.98. Since the test statistic is greater than the critical value of 2.71, the smaller discrimination stage detection rate is considered to be significantly less at the 0.05 level of significance. While a significant result does not prove a cause and effect relationship exists between the change in survey area and degradation in performance, it does indicate that the ability of demonstrator X to correctly discriminate seems to have been degraded by the mogul terrain relative to results from the flat open field using the same system.

APPENDIX B. DAILY WEATHER LOGS

Date, 05	Time	Average Temperature, ^{o}F	Average Precipitation, in.
5 Oct	0700	62.9	0.00
	0800	64.5	0.00
	0900	65.8	0.00
	1000	67.3	0.00
	1100	68.1	0.00
	1200	68.5	0.00
	1300	70.6	0.00
	1400	73.2	0.00
	1500	75.7	0.00
	1600	77.2	0.00
	1700	78.1	0.00
6 Oct	0700	66.5	0.00
	0800	66.9	0.00
	0900	68.1	0.00
	1000	69.0	0.00
	1100	69.7	0.00
	1200	70.3	0.00
	1300	72.8	0.00
	1400	74.7	0.00
	1500	76.7	0.00
	1600	77.5	0.00
	1700	74.9	0.00
7 Oct	0700	71.9	0.00
	0800	72.2	0.00
	0900	73.3	0.00
	1000	74.2	0.00
	1100	74.7	0.01
	1200	75.8	0.00
	1300	77.4	0.00
	1400	77.9	0.01
	1500	76.3	0.05
	1600	76.3	0.13
	1700	76.0	0.01

Date, 05	Time	Average Temperature, °F	Average Precipitation, in.
18 Oct	0700	50.6	0.00
	0800	54.0	0.00
	0900	55.9	0.00
	1000	59.7	0.00
	1100	67.2	0.00
	1200	72.5	0.00
	1300	74.3	0.00
	1400	75.5	0.00
	1500	75.5	0.00
	1600	76.5	0.00
	1700	76.8	0.00
19 Oct	0700	44.2	0.00
	0800	43.6	0.00
	0900	50.2	0.00
	1000	58.0	0.00
	1100	63.3	0.00
	1200	66.8	0.00
	1300	68.5	0.00
	1400	69.9	0.00
	1500	70.9	0.00
	1600	71.9	0.00
	1700	71.7	0.00
20 Oct	0700	58.2	0.00
	0800	56.6	0.00
	0900	55.7	0.00
	1000	54.3	0.00
	1100	53.9	0.00
	1200	54.4	0.00
	1300	54.5	0.00
	1400	55.2	0.00
	1500	55.3	0.00
	1600	54.6	0.00
	1700	53.2	0.00

Date, 05	Time	Average Temperature, ^oF	Average Precipitation, in.
21 Oct	0700	54.1	0.00
	0800	53.1	0.01
	0900	49.9	0.03
	1000	49.7	0.04
	1100	49.9	0.03
	1200	50.7	0.03
	1300	51.2	0.01
	1400	51.5	0.00
	1500	51.6	0.00
	1600	51.4	0.00
	1700	51.3	0.00

APPENDIX C. SOIL MOISTURE

Date: 5 October 2005			
Times: 1100 through 1600			
Probe Location:	**Layer, in.**	**AM Reading, %**	**PM Reading, %**
Wet area	0 to 6	NA	NA
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Wooded area	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open field	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Calibration lanes	0 to 6	0.4	0.4
	6 to 12	14.1	14.0
	12 to 24	22.1	21.8
	24 to 36	26.4	26.3
	36 to 48	27.2	27.0
Blind grid/moguls	0 to 6	2.0	2.0
	6 to 12	4.2	4.1
	12 to 24	22.3	22.4
	24 to 36	3.1	3.0
	36 to 48	2.3	2.4

Date: 6 October 2005			
Times: 0800 through 1600			
Probe Location:	**Layer, in.**	**AM Reading, %**	**PM Reading, %**
Wet area	0 to 6	NA	NA
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Wooded area	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open field	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Calibration lanes	0 to 6	0.3	0.3
	6 to 12	13.9	14.2
	12 to 24	21.4	21.2
	24 to 36	26.4	26.0
	36 to 48	27.2	27.2
Blind grid/moguls	0 to 6	1.9	1.9
	6 to 12	4.0	4.0
	12 to 24	22.2	22.1
	24 to 36	2.8	2.8
	36 to 48	2.2	2.2

Date: 7 October 2005			
Times: 0900 through 1400			
Probe Location:	**Layer, in.**	**AM Reading, %**	**PM Reading, %**
Wet area	0 to 6	2.3	2.3
	6 to 12	4.0	3.9
	12 to 24	8.0	7.8
	24 to 36	2.2	2.1
	36 to 48	2.3	2.4
Wooded area	0 to 6	NA	NA
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open field	0 to 6	2.7	2.7
	6 to 12	3.0	2.9
	12 to 24	2.0	2.1
	24 to 36	6.4	6.2
	36 to 48	11.2	11.3
Calibration lanes	0 to 6	NA	NA
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Blind grid/moguls	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		

Date: 18 October 2005			
Times: 0800 through 1600			
Probe Location:	**Layer, in.**	**AM Reading, %**	**PM Reading, %**
Wet area	0 to 6	4.5	4.4
	6 to 12	7.9	8.1
	12 to 24	16.0	15.9
	24 to 36	4.4	4.3
	36 to 48	4.5	4.2
Wooded area	0 to 6	NA	NA
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open field	0 to 6	5.5	5.6
	6 to 12	6.0	6.2
	12 to 24	4.0	3.8
	24 to 36	12.5	12.9
	36 to 48	22.3	22.0
Calibration lanes	0 to 6	NA	NA
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Blind grid/moguls	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		

Date: 19 October 2005			
Times: 0800 through 1500			
Probe Location:	**Layer, in.**	**AM Reading, %**	**PM Reading, %**
Wet area	0 to 6	4.2	4.1
	6 to 12	8.0	8.2
	12 to 24	16.0	15.7
	24 to 36	4.1	4.0
	36 to 48	4.3	4.4
Wooded area	0 to 6	NA	NA
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open field	0 to 6	5.3	5.5
	6 to 12	6.2	6.6
	12 to 24	3.9	3.6
	24 to 36	12.3	12.7
	36 to 48	22.5	22.6
Calibration lanes	0 to 6	NA	NA
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Blind grid/moguls	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		

Date: 20 October 2005			
Times: 0800 through 1800			
Probe Location:	**Layer, in.**	**AM Reading, %**	**PM Reading, %**
Wet area	0 to 6	4.4	4.7
	6 to 12	8.6	8.5
	12 to 24	16.0	16.5
	24 to 36	4.5	4.7
	36 to 48	4.5	4.9
Wooded area	0 to 6	NA	NA
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open field	0 to 6	5.2	5.7
	6 to 12	6.5	6.9
	12 to 24	3.8	4.6
	24 to 36	12.2	12.9
	36 to 48	22.9	23.5
Calibration lanes	0 to 6	NA	NA
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Blind grid/moguls	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		

Date: 21 October 2005			
Times: 1000 through 1330			
Probe Location:	**Layer, in.**	**AM Reading, %**	**PM Reading, %**
Wet area	0 to 6	5.6	5.8
	6 to 12	9.5	9.9
	12 to 24	16.8	16.9
	24 to 36	5.8	5.9
	36 to 48	5.9	6.2
Wooded area	0 to 6	NA	NA
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open field	0 to 6	5.9	6.3
	6 to 12	7.5	7.8
	12 to 24	4.8	4.8
	24 to 36	13.8	13.8
	36 to 48	23.8	24.2
Calibration lanes	0 to 6	NA	NA
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Blind grid/moguls	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		

APPENDIX D. DAILY ACTIVITY LOGS

Date, 05	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min.	Operational Status	Track Method=Other Explain	Track Method	Pattern	Field Conditions
5 Oct	2	CALIBRATION LANES	1050	1330	160	INITIAL SET-UP	NA	GPS	LINEAR	SUNNY, DRY
	2	CALIBRATION LANES	1510	1545	35	INITIAL SET-UP	NA	GPS	LINEAR	SUNNY, DRY
6 Oct	2	CALIBRATION LANES	0740	1755	615	INITIAL SET-UP	NA	GPS	LINEAR	RAIN, WET
	2	BLIND TEST GRID	1755	1830	35	COLLECTING DATA	NA	GPS	LINEAR	RAIN, WET
	2	BLIND TEST GRID	1830	1905	35	DAILY START, STOP	NA	GPS	LINEAR	RAIN, WET
7 Oct	2	OPEN FIELD	0730	0815	45	DAILY START, STOP	NA	GPS	LINEAR	RAIN, WET
	2	OPEN FIELD	0815	1135	200	COLLECTING DATA	NA	GPS	LINEAR	RAIN, WET
	2	OPEN FIELD	1135	1150	15	BREAK/LUNCH	NA	GPS	LINEAR	RAIN, WET
	2	OPEN FIELD	1150	1340	110	COLLECTING DATA	NA	GPS	LINEAR	RAIN, WET
	2	OPEN FIELD	1340	1400	20	DAILY START, STOP	NA	GPS	LINEAR	RAIN, WET
	2	OPEN FIELD	1400	1415	15	DOWNTIME DUE TO EQUIP MAINT/CHECK	NA	GPS	LINEAR	RAIN, WET
	2	OPEN FIELD	1415	1430	15	DAILY START, STOP	NA	GPS	LINEAR	RAIN, WET
	2	OPEN FIELD	0740	0855	75	DAILY START, STOP	NA	GPS	LINEAR	SUNNY, DRY
	2	OPEN FIELD	0855	1205	190	COLLECTING DATA	NA	GPS	LINEAR	SUNNY, DRY
	2	OPEN FIELD	1205	1245	40	BREAK/LUNCH	NA	GPS	LINEAR	SUNNY, DRY
	2	OPEN FIELD	1245	1655	250	COLLECTING DATA	NA	GPS	LINEAR	SUNNY, DRY
	2	OPEN FIELD	1655	1800	65	DOWNTIME DUE TO EQUIPMENT FAILURE	NA	GPS	LINEAR	SUNNY, DRY
	2	OPEN FIELD	1800	1815	15	DAILY START, STOP	NA	GPS	LINEAR	SUNNY, DRY

Date, 05	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min.	Operational Status	Track Method=Other Explain	Track Method	Pattern	Field Conditions
18 Oct	2	OPEN FIELD	0740	1220	280	DOWNTIME DUE TO EQUIPMENT FAILURE	NA	GPS	LINEAR	SUNNY, DRY
	2	OPEN FIELD	1220	1710	290	COLLECTING DATA	NA	GPS	LINEAR	SUNNY, DRY
	2	OPEN FIELD	1710	1755	45	DAILY START, STOP	NA	GPS	LINEAR	SUNNY, DRY
19 Oct	2	OPEN FIELD	725	845	80	DAILY START, STOP	NA	GPS	LINEAR	SUNNY, DRY
	2	OPEN FIELD	0845	1530	405	COLLECTING DATA	NA	GPS	LINEAR	SUNNY, DRY
	2	OPEN FIELD	1530	1650	80	DAILY START, STOP	NA	GPS	LINEAR	SUNNY, DRY
20 Oct	2	OPEN FIELD	0725	0815	50	DAILY START, STOP	NA	GPS	LINEAR	CLOUDY, COOL
	2	ACTIVE SITE	0815	0845	30	COLLECTING DATA	NA	GPS	LINEAR	CLOUDY, COOL
	2	OPEN FIELD	0845	1015	90	COLLECTING DATA	NA	GPS	LINEAR	CLOUDY, COOL
	2	OPEN FIELD	1015	1405	230	DOWNTIME DUE TO EQUIPMENT FAILURE	NA	GPS	LINEAR	CLOUDY, COOL
	2	OPEN FIELD	1405	1525	80	COLLECTING DATA	NA	GPS	LINEAR	CLOUDY, COOL
	2	OPEN FIELD	1525	1715	110	DOWNTIME DUE TO EQUIPMENT FAILURE	NA	GPS	LINEAR	CLOUDY, COOL
	2	OPEN FIELD	1715	1810	55	DAILY START, STOP	NA	GPS	LINEAR	CLOUDY, COOL
21 Oct	2	ACTIVE SITE	0650	0755	65	DAILY START, STOP	NA	GPS	LINEAR	RAIN, WET
	2	ACTIVE SITE	0755	0850	55	COLLECTING DATA	NA	GPS	LINEAR	RAIN, WET
	2	ACTIVE SITE	0850	1115	145	DEMONSTRATION SITE ISSUE	NA	GPS	LINEAR	RAIN, WET
	2	ACTIVE SITE	1115	1240	85	COLLECTING DATA	NA	GPS	LINEAR	RAIN, WET
	2	OPEN FIELD	1240	1445	125	DEMOBILIZATION	NA	GPS	LINEAR	RAIN, WET

APPENDIX E.   REFERENCES

1. Standardized UXO Technology Demonstration Site Handbook, DTC Project No. 8-CO-160-000-473, Report No. ATC-8349, March 2002.

2. Aberdeen Proving Ground Soil Survey Report, October 1998.

3. Data Summary, UXO Standardized Test Site: APG Soils Description, May 2002.

APPENDIX F. ABBREVIATIONS

ADST = Aberdeen Data Services Team
APG = Aberdeen Proving Ground
ASCII = American Standard Code for Information Interchange
ATC = U.S. Army Aberdeen Test Center
ATSS = Aberdeen Test and Support Services
BAR = Background Alarm Rate
DMM = discarded military munitions
EM = electromagnetic
EQT = Environmental Quality Technology
ERDC = U.S. Army Corps of Engineers Engineering Research and Development Center
ESTCP = Environmental Security Technology Certification Program
GPS = Global Positioning System
GT = ground truth
HDSD = Homeland Defense and Sustainment Division
MEC = munitions and explosives of concern
MTADS = Multiple Towed Array Detection System
NRL = Naval Research Laboratory
OE = ordnance and explosives
POC = point of contact
PVC = polyvinyl chloride
QA = quality assurance
QC = quality control
ROC = receiver-operating characteristic
SERDP = Strategic Environmental Research and Development Program
USAEC = U.S. Army Environmental Command
UXO = unexploded ordnance

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